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**United States Coast Guard
Integrated Risk Assessment Process**

Volume I



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| 16. Abstract (MAXIMUM 200 WORDS) Due to the new challenges (e.g., government downsizing, increased system complexity, ever-changing high-risk operations) faced by the Coast Guard, the Coast Guard Research and Development Center (RDC) was requested to explore the possibility of applying system safety concepts, including the use of risk analysis and enhancement of inspection procedures, to improve Coast Guard operations and facility safety. The Coast Guard RDC teamed with JBF Associates, Inc. (JBFA), a consulting firm specializing in hazard and risk analysis/management, to develop a risk-based loss prevention program. The initial focus was on developing one portion of the risk-based loss prevention program, a risk assessment process. This report discusses the development, validation, and end product (the Integrated Risk Assessment [IRA] process) of this effort. Effective implementation of the IRA process provides the Coast Guard with risk-based information for: (1) controlling and reducing loss exposure, (2) making risk-based decisions, and (3) using limited resources more efficiently. The IRA process proved to be an effective and efficient risk assessment tool for various types of vessels and their operations, as well as shore facilities and their operations. This report contains three volumes: Volume I consists of the main text of the report and Attachment A: Integrated Risk Assessment (IRA) Manual. Volume II consists of Attachment B: Coarse Hazard Analysis of a WMEC-210 Vessel in Support of the Paragon Project, and Attachment C: Coarse Hazard Analysis of the Integrated Support Command (ISC) at Seattle, WA. Volume III consists of Attachment D: Detailed Hazard Analysis of WMEC-270 Small Boat Operations, Attachment E: Detailed Hazard Analysis of WLIC-160 Deck Operations, and Attachment F: Risk-based Safety Survey of a WMEC-378 Vessel. | | | | | |
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EXECUTIVE SUMMARY

Integrated Risk Assessment (IRA) Program

This report describes the efforts within the Loss Exposure and Risk Methodology (LERAM) project during 1996-1997 to develop a forward-looking loss system for the U.S. Coast Guard. The IRA program integrates risk assessment and traditional safety survey activities to identify, characterize, and monitor hazards and safeguards from a risk prioritization perspective. In addition, the IRA provides the risk characterization information needed for risk management activities that are currently being developed and integrated into existing Coast Guard management practices. Risk characterization information is obtained from a variety of data sources and subject matter expert (Coast Guard operations and maintenance personnel) assessments facilitated by trained assessment facilitators (Coast Guard health and safety staffs).

The IRA program is a systematic, predictive approach for characterizing risks associated with operational and maintenance activities and preventing potential losses. The program approach is to characterize total risk to a Coast Guard unit or facility. Characterizing how inherent hazards can produce losses, assessing the types/levels of safeguards needed, developing recommendations for reducing risks, and generating risk profiles for operations/facilities enables Coast Guard leadership to effectively manage risk. Possibly, just as important, since operational personnel characterize the hazard and safeguard interplay involved with accident scenarios, their understanding, awareness, will lead to personal risk reduction measures.

Risk information is used to assist in assessing the significance and importance of safeguards for preventing or mitigating losses. Safeguards can be ranked based on their contribution to the overall risk and monitored appropriately. Understanding safeguard contributions to risk enables the scope and number of safety surveys to be modified to more effectively employ trained safety professionals. In addition, characterizing the effectiveness of safeguards provides valuable information to correct, modify, or eliminate safeguards to reduce risk and reduce maintenance and monitoring resources.

The Coast Guard Integrated Risk Assessment (IRA) Program addresses risks from the perspective deemed most appropriate by Coast Guard operations, maintenance, health and safety, and program personnel. Industry accepted techniques, definition, and measures of success were used as the basis for a process that provides the Coast Guard with the means necessary to

effectively identify, assess, and manage risk. It is a scientific, predictive approach, based on both historical information and expert judgment.

The Integrated Risk Assessment program consists of a both coarse and detailed risk analysis processes, the integration of risk assessment into our established safety survey practice, and necessary training, techniques, and tools. The critical management systems necessary to support such a program and ensure its integration into other critical business practices are currently under development. The Coast Guard's risk management program while being incrementally developed and fielded will completely transition from the research and development phase by the year 2001.

As with industry and other government agencies, the Coast Guard expects risk assessment/management methods to be continuously revised to account for different types of loss exposures, new technologies that affect data, analysis, documentation, and communication of the results, and changing requirements.

Table of Contents

| <u>Section</u> | <u>Page</u> |
|--|--------------------|
| Executive Summary..... | vi |
| 1. Introduction..... | 1 |
| 2. Background..... | 4 |
| 3. Guiding Principles..... | 10 |
| 4. IRA Process Description..... | 11 |
| 4.1 Risk Analysis Process..... | 12 |
| 4.1.1 Coarse Risk Analysis..... | 12 |
| 4.1.1.1 Coarse Risk Analysis Steps | 13 |
| 4.1.1.2 Coarse Risk Analysis Results..... | 14 |
| 4.1.2 Detailed Risk Analysis..... | 19 |
| 4.2 Risk-based Safety Survey Process | 20 |
| 4.2.1 Risk-based Safety Survey Steps..... | 22 |
| 4.2.2 Risk-based Safety Survey Results..... | 23 |
| 4.3 Risk Analysis and Risk-based Safety Survey Process Integration | 24 |
| 4.4 Making Decisions Using the IRA Process..... | 25 |
| 5. IRA Process Development | 28 |
| 5.1 Phase 1 | 29 |
| 5.1.1 Risk Analysis | 29 |
| 5.1.1.1 Coarse Risk Analysis..... | 29 |
| 5.1.1.2 Detailed Risk Analysis..... | 31 |
| 5.1.2 Risk-based Safety Survey | 33 |
| 5.2 Phase 2 | 34 |
| 5.2.1 Coarse Risk Analysis..... | 35 |
| 5.2.2 Detailed Risk Analysis..... | 37 |
| 5.2.3 Risk-based Safety Survey | 38 |
| 5.3 Phase 3 | 39 |
| 5.3.1 Coarse Risk Analysis..... | 39 |
| 6. Future Development | 41 |
| 7. Concluding Remarks..... | 42 |

Table of Contents (cont'd)

| <u>Section</u> | <u>Page</u> |
|--|-------------|
| Attachment A | |
| <i>Integrated Risk Assessment (IRA) Manual</i> | A-1 |
| Attachment B | |
| <i>Coarse Hazard Analysis of a WMEC-210 Vessel in Support of the Paragon Project</i> | B-1 |
| Attachment C | |
| <i>Coarse Hazard Analysis of the Integrated Support Command (ISC) at Seattle, Washington</i> | C-1 |
| Attachment D | |
| <i>Detailed Hazard Analysis of WMEC-270 Small Boat Operations</i> | D-1 |
| Attachment E | |
| <i>Detailed Hazard Analysis of WLIC-160 Deck Operations</i> | E-1 |
| Attachment F | |
| <i>Risk-based Safety Survey of a WHEC-378 Vessel</i> | F-1 |

List of Figures

| <u>Figure</u> | <u>Description</u> | <u>Page</u> |
|---------------|--|-------------|
| 1.1 | IRA Process | 2 |
| 2.1 | Risk Management | 7 |
| 4.1 | Integrated Risk Assessment (IRA) Process | 11 |
| 4.2 | Identification of Hazards and Their Associated Risk..... | 15 |
| 4.3 | Risk Matrix Characterizing a Coast Guard Unit | 16 |
| 4.4 | Percentage of Total Risk of Operations/Evolutions | 16 |
| 4.5 | Range of Mishap Frequencies for Assets | 17 |
| 4.6 | Cost/Benefit Analysis for Implementing Risk Reduction Recommendations..... | 19 |

List of Figures (cont'd)

| <u>Figure</u> | <u>Description</u> | <u>Page</u> |
|---------------|--|-------------|
| 4.7 | Basis for the Risk-based Safety Survey Process..... | 21 |
| 4.8 | Risk Impact of a Risk-based Safety Survey Finding..... | 24 |
| 4.9 | Results of a Root Cause Analysis..... | 24 |
| 4.10 | IRA Information Exchanges..... | 25 |

List of Tables

| <u>Table</u> | <u>Description</u> | <u>Page</u> |
|--------------|---|-------------|
| 2.1 | Comparison of Risk Management Perspectives | 9 |
| 4.1 | Coarse Risk Analysis Recommendations | 18 |
| 4.2 | Detailed Risk Analysis Techniques..... | 20 |
| 4.3 | Uses of the IRA Process for Vessel Life Cycle Activities..... | 26 |

List of Acronyms and Abbreviations

| | |
|----------|---|
| ATON | Aids to Navigation |
| ESU | Electronic Support Unit |
| FMEA | Failure Mode and Effects Analysis |
| HAZOP | Hazard and Operability Analysis |
| IRA | Integrated Risk Assessment |
| ISA | Integrated Safety Assessment |
| ISC | Integrated Support Command |
| LERAM | Loss Exposure and Risk Analysis Methodology |
| MLC-LANT | Maintenance Logistics Command, Atlantic |
| MLC-PAC | Maintenance Logistics Command, Pacific |
| MSO | Marine Safety Office |
| NESU | Naval Engineering Support Unit |
| RDC | U.S. Coast Guard Research and Development Center |
| RIN | Risk Index Number |
| WHEC | High Endurance Cutter |
| WISE | Worker and Instruction Safety Evaluation Analysis |
| WMEC | Medium Endurance Cutter |
| WLIC | Construction Tender |

1. Introduction

As part of the United States Coast Guard's (Coast Guard's) Safety Program, the Research and Development Center (RDC) was requested to explore the possibility of applying system safety concepts, including the use of risk analysis and the enhancement of the safety survey process with risk-based information, to improve Coast Guard operations and facility safety. This research was executed under the Coast Guard Loss Exposure and Risk Analysis Methodology (LERAM) project. The Coast Guard RDC teamed with JBF Associates, Inc. (JBFA), a consulting firm specializing in hazard and risk analysis/management, to develop a risk-based loss prevention program consisting of a risk assessment methodology (techniques and tools) and a risk management program. This report documents the development of the risk assessment methodology and presents the methodology.

Development of the methodology began in 1995 with the following objectives:

- Develop practical approaches for estimating risk exposure for various Coast Guard activities so that managers can use the risk-based information in decision making
- Identify/develop efficient and effective risk analysis approaches for providing the information that Coast Guard personnel will need for decision making
- Demonstrate the effectiveness of the selected risk analysis approaches
- Enhance the Coast Guard safety survey process to make it more efficient and effective by focusing on significant risks and reducing emphasis on unnecessary requirements
- Integrate risk analysis and safety surveys to provide reliable measures of risk exposure associated with Coast Guard missions

The result of achieving these objectives is the Integrated Risk Assessment (IRA) process. The IRA process provides the Coast Guard with the means necessary to effectively manage and control risk at its units (both vessels and shore facilities). The process supplies risk-based information to aid Coast Guard personnel in making tactical as well as long-term strategic decisions. It is a systematic, predictive approach (based on both historical information and expert judgment) for understanding the risk associated with Coast Guard activities and preventing potential losses within the Coast Guard by:

- Identifying how inherent hazards associated with Coast Guard operations/facilities can produce potential losses
- Characterizing the risks of potential losses
- Assessing the types/levels of safeguards needed to effectively manage the identified risks
- Helping to ensure that safeguards adopted by the Coast Guard are effectively implemented in the field
- Developing recommendations for reducing risks (i.e., better safeguards for operations/facilities)
- Producing risk profiles for operations/facilities that Coast Guard managers can use to manage Coast Guard risks

As shown in Figure 1.1, the IRA process has two distinct, yet closely related, parts: (1) risk analysis process (which is divided into coarse risk analysis and detailed risk analysis) and (2) risk-based safety survey process.

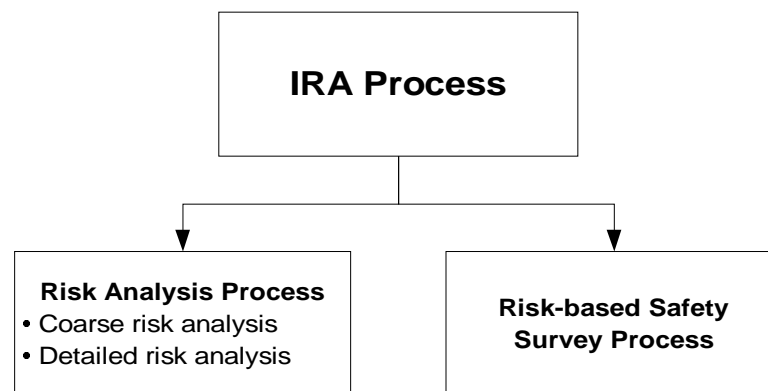


Figure 1.1 IRA Process

Coarse risk analysis is a team-oriented, high-level (coarse), predictive analysis tool for identifying hazards, potential mishaps (losses), safeguards, risk associated with the mishaps, and recommendations for reducing risk. The coarse risk analysis tool is designed to be performed by Coast Guard safety professionals who have received modest risk assessment training.

Detailed risk analysis is a collection of standard, industry-proven, predictive analysis tools that can be used when specific results with a higher degree of resolution and/or certainty are required. The detailed risk analysis tools require an experienced analyst.

The risk-based safety survey process is a process for systematically ensuring that the safeguards designed to control risk are being effectively implemented in the field. The process uses risk-based information to reduce the total resources required to effectively control overall risk by focusing those resources on the issues associated with the most significant risks. It includes a combination of field observations of equipment status as well as direct reviews of management programs/documentation. This highlights where safeguard implementation weaknesses are increasing risks. The risk-based safety survey process also includes methods for determining the root causes of deficiencies. The process may be performed by Coast Guard safety professionals or even unit safety supervisors who have modest training.

The remainder of this report is divided into six sections. Section 2 (Background) discusses (1) the circumstances that have led the Coast Guard to explore the development of a risk assessment process, (2) risk fundamentals, and (3) the purpose and benefits of a risk assessment process. Section 3 (Guiding Principles) discusses the 10 principles the RDC and JBFA followed during the development of a Coast Guard risk assessment process. Next, Section 4 (IRA Process Description) familiarizes the reader with the final results of the Coast Guard risk assessment process development by providing a brief explanation of the various parts of the IRA process. The approach used to develop the IRA process, as well as the results of validating the process, are discussed in Section 5 (IRA Process Development). A discussion of future work that will focus on Coast Guard risk management systems is included in Section 6 (Future Development). Section 7 (Concluding Remarks) contains final thoughts about the IRA process. The attachments to this report include the *IRA Manual* (which fully documents the IRA process) and example applications of the IRA process on vessel and shore assets

Note: During the course of this research project, the term “hazard analysis” was changed to “risk analysis” to better describe the process. Therefore, the term “hazard analysis” will be found in many previous letters, reports, and other work products related to this project. These previous references to hazard analysis should now be interpreted as references to risk analysis.

2. Background

History of Risk Assessment

Modern risk assessment has roots in probability theory and scientific methods for identifying causal links between adverse health effects and different types of hazardous activities. In 1792, Pierre Simon de LaPlace demonstrated a modern quantitative risk assessment by calculating the probability of death associated with and without receiving the smallpox vaccination. Insurance may be one of the oldest strategies for dealing with risk. In 1950 B.C., the Code of Hamurabi formalized bottomry contracts containing a risk premium for the chance of loss of ships and cargo and in 1583 the first life insurance policy was issued in London.

Risk mitigation measures in the form of water and garbage sanitation in the 19th and 20th centuries were extremely successful in decreasing the risk of mortality and morbidity. Along similar lines, building and fire codes, boiler testing and inspection, and safety engineering on steamboats, railroads and automobiles greatly contributed to public safety. A whole field of risk management was developed based on common sense risk analysis, which increased the longevity and generally improved the quality of life for most citizens in industrialized countries.

Conceptual development of modern risk analysis in the United States and other industrially developed countries rose from the potentially catastrophic consequences and uncertainty associated with high hazard industries such as nuclear power, chemical processing, aviation, and modern weapon systems. In addition, increased awareness and demand for public safety in industrialized environments led governments to establish agencies similar to our Environmental Protection Agency, Occupational Safety and Health Administration, and the National Institute for Occupational Safety and Health.

Evolution

Formal risk assessment studies initially focused on the potential causes and consequences of major events that could involve large numbers of injuries or economic impact, such as explosions and release of toxic substances. Typically, a risk assessment focused on ways that equipment failures, software problems, human errors, and external factors (e.g., weather) contributed to losses. Risk assessments typically did not include industrial health and safety issues, although these can significantly contribute to the total losses experienced by an organization.

These initial assessment techniques are characterized by a strong emphasis on quantitative information. This initial emphasis continues to have a strong influence on the thinking of many risk management practitioners, in that qualitative assessments involve human judgement, thus are inherently unreliable or inaccurate. These initial techniques were designed to scientifically address all aspects of complex systems and facilitate analysis and what-if scenarios to be considered independent of human analysis.

As experience was gained in the field of risk assessment, and more industries began to see the benefits of assessing loss exposure, less expensive and more robust methods were needed to offset the expertise and data requirement demands of strictly quantitative techniques. Semi-quantitative techniques were developed to incorporate subject matter expertise with hard data.

As engineered systems became more reliable and accident scenario and risk contribution awareness grew, emphasis began shifting toward human performance and management systems. These contributors had the potential to effect a wide variety of loss scenarios and their failure rates were not well understood.

Perspective

There are a variety of ways to describe risk and many definitions are products of established manufacturing and health industries. Chemicals risks, for example, are traditionally viewed in terms of acute toxicity, subchronic and chronic toxicity, cancer potency, dose vs. response, and exposure. Chemical risk assessments often address the establishment of concentrations that could be tolerated by most people without adverse health effects. Environmental awareness has broadened the perspective of chemical risk assessment to include impacts to the environment that may or may not impact public health.

Coast Guard Safety Experience

The Coast Guard, like many organizations, adheres to a traditional safety program emphasizing prescriptive codes, mishap (loss or accident) reporting, and incident investigations. The basic risk analysis tools that the Coast Guard has traditionally relied upon are the warning flags obtained from reported mishaps, single significant events, hazardous condition notifications, and periodic safety audits. Anomalies in mishap trends, significant losses, anomalous safety audit findings, and reported hazards are benchmarked against the Coast Guard “corporate experience.”

Over time, the Coast Guard has made a series of improvements to the mishap reporting procedures to provide greater resolution of the factors involved in losses and to help ensure consistently accurate reporting. The organization has strived to address such issues as human errors, the importance of root causes, the importance of management's risk acceptance level, and the shortcomings of electronic databases.

The Coast Guard realized that government downsizing, rapidly changing technologies, increased system complexities, rising construction and repair costs, high turnover rates, and ever-changing high-risk operations may erode the low incident rate and good safety record of its traditional safety program. To address these new challenges, the Coast Guard decided to make a concerted effort to understand and apply industry-proven loss prevention and risk management practices to its operations and facilities. This effort involves developing a risk-based loss prevention program for the Coast Guard, which includes risk assessment techniques and tools under the umbrella of an overall risk management program.

The Coast Guard initially focused on developing risk assessment techniques and tools (the topic of this report). Before going any further, it is advantageous to briefly discuss risk, risk assessment, and risk management.

Risk is defined as the combination of the expected frequency and consequence of losses that could occur as a result of an activity. Understanding risk includes addressing the following three questions:

- What can go wrong?
- How likely is it?
- What are the impacts?

Therefore, analyzing risk involves identifying losses of interest (What can go wrong?), estimating the frequency of occurrence (How likely is it?), and evaluating the potential consequences (What are the impacts?).

Risk cannot be completely eliminated; however, it can be managed. Many risks are accepted as a cost of doing business. In controlling losses, it is important to (1) understand the associated risks, (2) understand the means used to control the risks, (3) understand the level of acceptable risk (accepted cost of doing business), and (4) identify and manage safeguards to reduce unacceptable risk.

Risk assessment is the systematic process of identifying potential losses and characterizing the frequencies and severities of those losses. This process focuses on understanding loss exposure based on existing conditions/protections (safeguards) as well as generating recommendations for additional safeguards as appropriate.

Risk management is the use of Coast Guard management policies, procedures, and practices (management systems) to control Coast Guard risks. Figure 2.1 shows the relationship between risk management with risk assessment (IRA process) and Coast Guard management systems used to control risk. (Attachment A, Sections 1 through 3, contain more detailed information on risk, risk assessment, and risk management.)

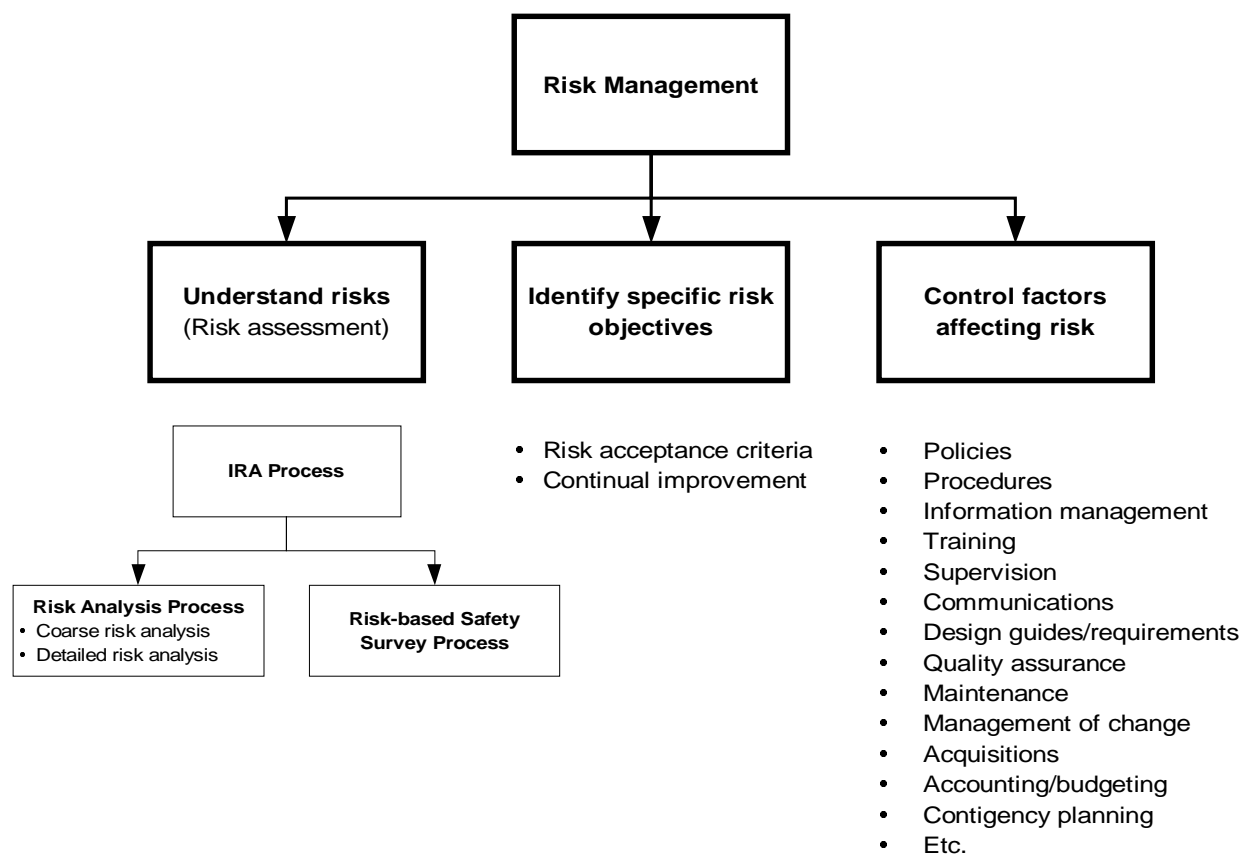


Figure 2.1 Risk Management

In general, there are two approaches to managing risk. One could be called the fly-fix-fly approach. This technique of not taking action until an accident occurs has been proven to be quite costly in terms of personnel injuries, property damage, and environmental consequences.

The second approach could be called the proactive approach. This approach, with risk assessment as a cornerstone, allows management the opportunity to eliminate or reduce risks to an acceptable level before losses occur.

While the Coast Guard is encouraged to operate with fewer and fewer resources (both equipment and personnel), more emphasis is placed on controlling losses and reducing loss exposure. The Coast Guard cannot afford to operate under a fly-fix-fly philosophy. It recognizes the advantages of developing measures to understand how losses occur, and it is committed to designing and maintaining safeguards (e.g., policies, procedures, systems, equipment) to prevent these losses from occurring (a proactive approach to loss prevention).

A risk assessment methodology is a proactive tool used for controlling losses and reducing loss exposure. The risk-based information from a risk assessment process (1) provides decision makers with the ability to focus resources in the most effective and efficient manner to reduce losses and (2) helps them make strategic and operational decisions that reduce loss exposure (e.g.: Can the operation be performed safely in these conditions? Should equipment A or B be purchased? Should equipment C be maintained more often than equipment D?). The RDC and JBFA developed the IRA process (risk analysis process and risk-based safety survey process) to fulfill the Coast Guard's risk assessment needs.

Table 2.1 shows two perspectives on Coast Guard risk management. One is Coast Guard risk management from a historical perspective (before). The other perspective is Coast Guard risk management after implementation of the IRA process (after). The table includes the approach for achieving risk understanding and risk control and the cost and effectiveness of risk management.

Table 2.1 Comparison of Risk Management Perspectives

| | Risk Understanding Approach | Risk Control Approach | Risk Management Effectiveness | Cost to the Coast Guard |
|---------------|--|--|---|---|
| Before | Historical <ul style="list-style-type: none"> • using past mishap information for addressing potential losses | Reactive <ul style="list-style-type: none"> • historical event focus • fly-fix-fly | <ul style="list-style-type: none"> • manages historically repeated events • will not adequately predict and prevent losses that have not occurred previously or identify and correct root causes • no risk prioritization to direct management of safeguards • higher loss exposure due to changes from historical operations and uncorrected root causes | High <ul style="list-style-type: none"> • significant effort for collection and management of information related to safeguard management • must ensure all safeguards (regardless of associated risk) are maintained at the same level • losses due to recurring losses and uncorrected root causes |
| After | Predictive <ul style="list-style-type: none"> • using historical information and expert judgment to predict potential losses | Proactive <ul style="list-style-type: none"> • predicted event focus • root cause focus • based on historical information as well as expert judgment | <ul style="list-style-type: none"> • manages both historical events and other future high risk events • identifies and corrects root causes • prioritizes safeguards to reduce resources required for safeguard management • lower loss exposure due to proactive loss prevention | Moderate <ul style="list-style-type: none"> • risk analysis requires higher initial setup cost • focused information collection and safeguard management based on risk-based prioritization of safeguards • reduced cost of losses due to a proactive loss prevention approach and the elimination of root causes |

3. Guiding Principles

To develop the risk assessment process (the IRA process), the RDC and JBFA followed 10 guiding principles. They are as follows:

- (1) **Consistent with Coast Guard culture** — The risk assessment process must be consistent with the Coast Guard management style, data-keeping strategies, and internal/external regulatory requirements.
- (2) **Generically applicable to all types of Coast Guard operations and facilities** — The process must be capable of assessing various types of vessels and their operations as well as shore facilities and their operations.
- (3) **Flexible enough not to overwork or underwork an issue** — The process must be capable of assessing an issue at the appropriate level of detail required to provide adequate results for Coast Guard decision making.
- (4) **Practical for Coast Guard personnel to implement** — The process should not be unnecessarily complicated. Coast Guard personnel who have moderate risk analysis training should be capable of successfully using the process.
- (5) **Designed to make maximum use of existing Coast Guard processes and information** — The process should not “re-invent the wheel.” Existing Coast Guard processes and information should be integrated into the risk assessment process where appropriate.
- (6) **Based on solid risk assessment fundamentals** — The foundation for the process should be built on solid risk assessment fundamentals that have been proven over time across a variety of applications.
- (7) **Based on predictive reasoning techniques as well as historical perspective techniques** — The process must be capable of identifying the means by which losses occur (before they occur) and provide the Coast Guard with information that will allow it to implement measures to prevent these losses from occurring. The process must also take advantage of past mishap information to help the Coast Guard control future losses.
- (8) **Useful to all branches of the Coast Guard in their decision making** — The process

should produce results that are easily understood and are useful to all levels of Coast Guard management.

- (9) **Focused on eliminating root causes of problems, not just symptoms** — The process should identify root causes of deficiencies and losses and provide the Coast Guard with the information necessary to prevent these root causes.
- (10) **Useful in focusing Coast Guard analysis, prevention, and corrective action resources on the most significant risks** — The risk-based information produced by the process should help the Coast Guard efficiently and effectively allocate its limited resources in reducing loss exposure.

Following these guiding principles when developing the IRA process produced efficient and effective risk assessment techniques/tools for the Coast Guard.

4. IRA Process Description

The IRA process consists of two subprocesses: (1) risk analysis and (2) risk-based safety survey. Figure 4.1 is a representation of the IRA process. Ellipses such as “Coast Guard loss experience” are types of information used in the risk analysis and risk-based safety survey processes. Hexagons such as “Risk profiles” are types of information these processes provide to Coast Guard management for risk-based decision making.

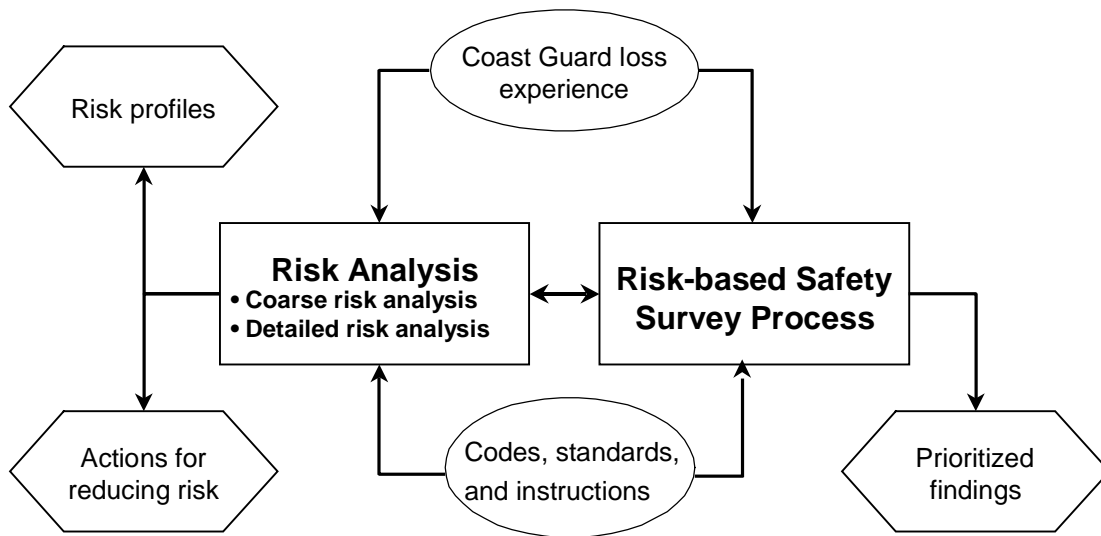


Figure 4.1 Integrated Risk Assessment (IRA) Process

This section briefly discusses the main elements of the IRA process and the steps involved in performing the process. Sections 4 through 8 of Attachment A, *Integrated Risk Assessment (IRA) Manual*, provide a more detailed description of the process as well as the detailed steps for performing the process.

4.1 Risk Analysis Process

The objectives for performing risk analyses include:

- Fewer losses over the life of platforms/facilities
- Reduced consequences when losses occur
- Improved training and understanding of system interactions and the effect of the human element
- More efficient and productive mission execution

A risk analysis involves:

- Identifying hazards systematically
- Postulating combinations of equipment failures/human errors/external events that allow the hazards to cause losses
- Characterizing the risks of the potential losses
- Identifying the most significant contributors to risk
- Providing summaries of risks (profiles) associated with various platforms/operations/functions
- Developing effective recommendations for better management of the known risks

The risk analysis process of the IRA process includes a set of tools (coarse and detailed risk analyses) for performing different types of hazard/risk analysis at various levels of detail.

4.1.1 Coarse Risk Analysis

Coarse risk analysis is the cornerstone and workhorse of the risk analysis methodology for the Coast Guard. It is designed to be performed by Coast Guard personnel and to satisfy most of the Coast Guard's needs for hazard/risk information in a practical and efficient manner. This method provides all of the types of results of more detailed evaluations, but with a lower degree of resolution. The coarse risk analysis methodology was developed from the hazard and

operability analysis technique used by the petrochemical industry. The methodology uses a team approach for postulating upsets to normal operations that could lead to undesirable consequences. The following are characteristics of a coarse risk analysis:

- Generally applicable to all types of Coast Guard platforms
- Capable of satisfying 60% to 90% of the Coast Guard's hazard/risk analysis needs without requiring the use of more detailed techniques
- Streamlined enough for efficient application without requiring extremely extensive evaluations
- Can be used by Coast Guard personnel who have modest risk analysis experience
- Built on solid hazard evaluation fundamentals that use not only historical perspective but also predictive reasoning

4.1.1.1 Coarse Risk Analysis Steps

Before discussing the steps of the coarse risk analysis, here are some definitions of terms that are important in understanding the steps of the analysis:

Operation/evolution — a specific operation performed in support of a Coast Guard mission
(e.g., boarding a vessel)

Function — a distinct activity that supports one or more operations/evolutions (e.g., operating vessels/craft)

Deviation — an off-normal condition or situation that has the potential to result in a mishap (loss)
(e.g., incorrect position/direction/speed)

There are five major steps in performing a coarse risk analysis:

- (1) **Determine the scope of the coarse risk analysis** — This step includes determining the equipment, system, unit, etc., to be analyzed. More specifically, it identifies the operations/evolutions and functions of the Coast Guard unit to be considered in the analysis.

- (2) **Screen low risk operations/evolutions, functions, deviations, and locations** — In this step, the operations/evolutions and functions are reviewed at a high level to eliminate lower risk issues from further analysis.
- (3) **Analyze deviations** — Analyzing deviations includes identifying causes, mishaps (losses), and safeguards applicable to each deviation within the scope of the analysis. This step also includes estimating risk associated with deviations and developing recommendations for reducing risk.
- (4) **Generate a risk profile** — This step involves using the data collected in Step 3 to characterize the risk for the Coast Guard unit being analyzed. Some examples of these characterizations are presented in the next section.
- (5) **Evaluate the benefit of risk reduction recommendations** — Step 5 determines the benefit of implementing the risk reduction recommendations developed during the analysis. Information from this step helps Coast Guard managers decide which recommendations to implement and in what order.

These steps are discussed in significant detail in Section 5 of Attachment A. The current set of operations/evolutions, functions, and deviations for vessels and shore facilities can be found in Section 9 of Attachment A.

4.1.1.2 Coarse Risk Analysis Results

The coarse risk analysis produces various results that enable Coast Guard personnel to make risk-based decisions and improve the management of risks associated with Coast Guard missions. Below is a sample of the types of risk-based management information available from the coarse risk analysis. Section 5 of Attachment A contains detailed instructions for obtaining these results and additional results that can be obtained from this technique. Attachments B and C provide an example of a coarse risk analysis for a Coast Guard vessel and shore facility, respectively.

An example of the data collected during a coarse risk analysis is shown in Figure 4.2. These results document the potential loss (mishap) scenarios associated with specific operations/evolutions and functions. These scenarios are based on possible deviations that may occur. Included are characterizations of the risk associated with the scenario using a combination

of frequency categories and mishap severity levels to estimate risk as a dollar/year loss considering potential safety, economic, mission, and environmental losses. Risk is expressed as a risk index number (RIN), which is the dollar/year loss divided by 10,000. RIN is calculated by using an average mishap cost and the lower bounds of the estimated frequency range of occurrence. The risk (dollar/year loss) is shown within parentheses under the RIN. Finally, a certainty estimate is assigned to the risk characterization.

| Coarse Risk Analysis | | | | | | | | | |
|--|--|---|-----------|---|---|------------------|-----------|--|--|
| Operation/Evolution: Working aids to navigation | | | | | | | | | |
| Function: Operating lifting equipment | | | | | | | | | |
| Deviation | Causes | Mishaps | Frequency | | | RIN† (Risk*) | Certainty | Safeguards | Recommendations |
| | | | A/B | C | D | | | | |
| 1.1 Loss of support | Crane cable/rigging failure Loss of power to the crane Structural failure in buoy during lifting | Equipment damage/loss Hazardous exposure: contact injury (dropped objects, broken lines, etc.) | 2 | 4 | 5 | 0.063 (\$630) | High | Boom is inspected annually Crew inspects crane daily and cable annually | Consider a formal preventive maintenance program for crane rigging and hardware Consider further investigation of the same, particularly during loss of power |

† Risk Index Number

* Estimated dollar/year loss considering safety, economic, mission, and environmental losses.

Figure 4.2 Identification of Hazards and Their Associated Risk

Figure 4.3 shows the number of loss scenarios (deviations) that are estimated to occur at a certain frequency and result in a certain magnitude of loss (class of mishap). The frequency is represented by a frequency category. For example, for the Class C mishap category in Figure 4.3, fifteen different deviations are considered Probable (Frequency Category 4). This risk profile is developed from the risk information collected during the coarse risk analysis (as shown in Figure 4.2).

| | | Class of Mishap | | |
|----------------------|-------------------|-----------------|----|----|
| Frequency Categories | | A/B | C | D |
| | Continuous (8) | 0 | 0 | 0 |
| | Very Frequent (7) | 0 | 2 | 2 |
| | Frequent (6) | 0 | 5 | 5 |
| | Occasional (5) | 1 | 9 | 9 |
| | Probable (4) | 2 | 15 | 22 |
| | Improbable (3) | 6 | 14 | 14 |
| | Rare (2) | 11 | 17 | 10 |
| | Remote (1) | 36 | 20 | 3 |
| | Incredible (0) | 9 | 4 | 0 |

Figure 4.3 Risk Matrix Characterizing a Coast Guard Unit

A risk histogram of the operations/evolutions of a vessel is shown in Figure 4.4. The risk contribution or contribution of the operation/evolution to overall vessel risk is presented. This information can be used to identify the higher risk operations/evolutions. Similar histograms are typically developed for functions, types of deviations, types of mishaps (losses), locations, etc. A category with a low risk level may be an indication of the safeguard levels designed to eliminate or mitigate the risk of an inherently dangerous operation/evolution and not just relatively safe operation or evolution.

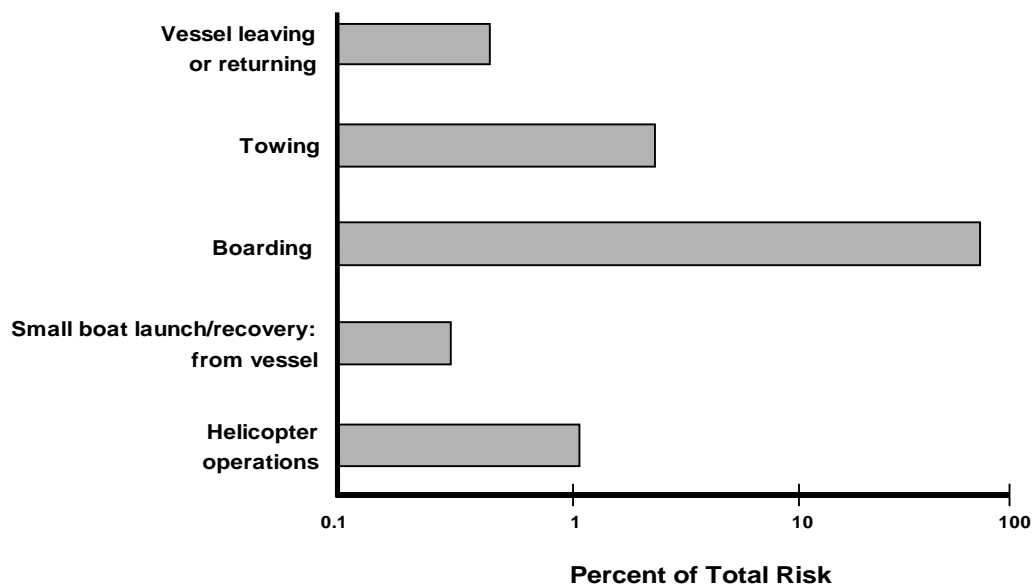


Figure 4.4 Percentage of Total Risk of Operations/Evolutions

Figure 4.5 displays an estimated frequency range of mishaps (losses) per year and expected number of mishaps over 50 years for a typical vessel in a vessel class. The table also includes the estimated frequency for mishaps for the entire vessel class.

| Vessel Class | Typical Vessel Frequency Bounds for Mishaps (per year) | | | Typical Vessel Expected Number of Occurrences over 50 Years | | | Vessel Class Frequency Bounds for Mishaps (per year) | | |
|-----------------------|--|-----------|-----------|---|-----------|---------------|--|-----------|-------------|
| | A/B | C | D | A/B | C | D | A/B | C | D |
| Vessel Class 1 | 0.13 to 1.3 | 1.4 to 14 | 26 to 261 | 7 to 65 | 70 to 700 | 1300 to 13000 | 1.3 to 13 | 14 to 140 | 261 to 2610 |
| Vessel Class 2 | 0.002 to 0.03 | 0.2 to 2 | 7 to 70 | 10% chance to 2 | 10 to 100 | 350 to 3500 | 0.014 to 0.21 | 1.4 to 14 | 49 to 490 |

Figure 4.5 Range of Mishap Frequencies for Assets

Table 4.1 shows two example recommendations developed by a coarse risk analysis team and the estimated change in RIN of associated coarse risk analysis deviations if the recommendations are implemented. Change in RIN is determined by estimating changes to the risk characterizations (See Figure 4.2). Shown within parentheses under the RIN is risk expressed as dollar/year loss. A positive number represents savings due to implementation of the recommendation. A negative number represents loss due to implementation. Change in RIN is also used to produce results such as those in Figure 4.6.

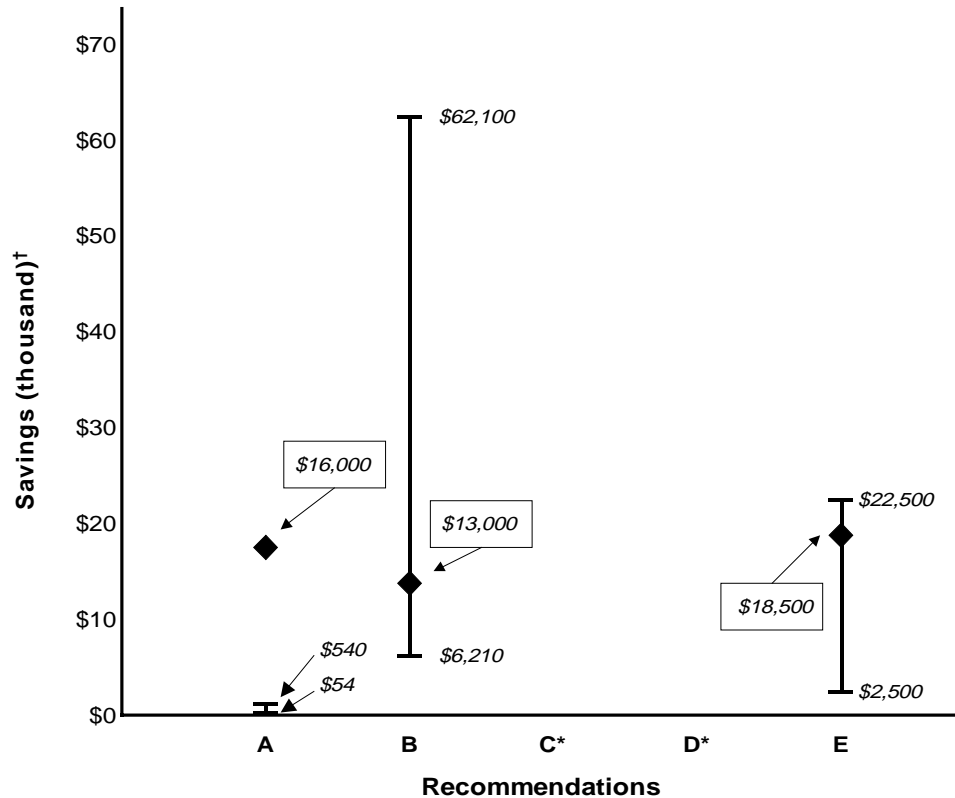
Table 4.1 Coarse Risk Analysis Recommendations

| Recommendation | Change in RINH (Risk*) |
|---|--------------------------|
| <p>Recommendation A — Consider modifying the ammunition dredger hoist to avoid crushing rounds and to incorporate personnel safety features, especially in regard to protecting hands/limbs. At least one significant personnel injury has occurred in the fleet while operating the hoist. This hazard is more pronounced in the lower ammunition magazine serviced by the hoist. At that location, personnel run the risk of (1) catching one or both hands in the hoist’s folding cover doors when loading an ammunition round, resulting in possible minor injury, or (2) having one or both hands severely injured if caught in the folding doors and the hoist subsequently moves upward, which would occur if the operator’s foot were to slip off a control pedal preventing hoist movement. The team also noted that hoist movement is stopped by contacting interlock switches (these interlocks may not be under any maintenance program). If these interlocks fail, an ammunition round may be crushed. Therefore, consider incorporating maintenance reviews of the ammunition dredger hoist into the Maintenance and Logistics Command (MLC) health and safety assessment process.</p> | <p>0.3 (\$3,000)</p> |
| <p>Recommendation B — Consider modifying the guides that keep the floating dock in place to (1) help prevent damage to the piles and (2) reduce the potential for personnel injury during maintenance (being caught between the guide and piles). The guides were designed for a cylindrical wood pile. The current piles are octagonal (or some other multisided geometric shape) and are made of concrete. The shape and design of the guides damage the piles and require frequent maintenance. A new guide design suited for the piles design should be chosen.</p> | <p>0.072 (\$720)</p> |

H Risk Index Number

* Estimated dollar/year savings if the recommendation is implemented.

Figure 4.6 displays the cost of implementing recommendations (shown in the boxes) as compared to the range of benefit (cost savings shown by the range) gained from the risk reduction. This range reflects the uncertainty of the frequency estimates in the analysis. This information aids decision makers when determining whether or not to implement a recommendation and in what order to implement recommendations.



* A reasonable estimate of savings is only possible after further review.

† Savings estimate assumes a \$300,000 average cost of Class A/B mishaps, a \$30,000 average cost of Class C mishaps, and a \$3,000 average cost of Class D mishaps.

◆ Estimated total cost of implementing recommendation.

Note: Savings shown account for 50-year life of a vessel.

Figure 4.6 Cost/Benefit Analysis for Implementing Risk Reduction Recommendations

4.1.2 Detailed Risk Analysis

Detailed risk analysis techniques are standard, industry-proven hazard/risk analysis methods providing better resolution of potential loss scenarios and more certainty in risk characterization of loss scenarios. For this reason, the IRA process includes an assortment of detailed risk analysis tools that can be used for specific Coast Guard applications. Table 4.2 presents these techniques and the rationale for their selection. These methods typically require more advanced levels of training for successful application and are used only when more detailed analysis is warranted. Considering the high cost of maintaining qualified evaluators and the expected relative low frequency of their use, the Coast Guard will typically contract out for a detailed risk analysis.

Table 4.2 Detailed Risk Analysis Techniques

| Technique | Rationale for Selection |
|--|--|
| What-if/Checklist | The simplicity and universal applicability of what-if/checklist analysis made it a natural choice for detailed hazard/risk analysis within the Coast Guard |
| WISE Analysis (<u>W</u> orker and <u>I</u> nstruction <u>S</u> afety <u>E</u> valuation Analysis) | The extensive nature of human involvement (especially procedural tasks) in virtually every Coast Guard mission/operation makes tools for thoroughly evaluating human error very important. The WISE analysis methodology combines into one technique an awareness of how people can impact processes and how processes can affect people |
| HAZOP Analysis (<u>H</u> azard and <u>O</u> perability Analysis) | This technique is similar in nature to WISE, but is more applicable to fluid and thermal systems, which are abundant on Coast Guard vessels. It provides a more structured approach than a what-if/checklist analysis to identifying hazard and operability problems stemming from system deviations |
| FMEA (<u>F</u> ailure <u>M</u> odes and <u>E</u> ffects Analysis) | The Coast Guard uses mechanical and electrical systems/equipment extensively, making FMEA a natural choice for these applications when a less structured what-if/checklist analysis may be inadequate. (Although HAZOP analysis could be useful for analyzing Coast Guard fluid and thermal systems, FMEA can be equally effective in such applications for Coast Guard systems) |
| FTA/ETA (<u>F</u> ault <u>T</u> ree <u>A</u> nalysis and <u>E</u> vent <u>T</u> ree <u>A</u> nalysis) | Because the Coast Guard has several systems with built-in redundancy and multiple levels of safeguards, modeling techniques for identifying complex combinations of equipment failures and human errors will be important for some situations. FTA/ETA are the most widely recognized and universally applicable techniques for these situations |
| HRA (<u>H</u> uman <u>R</u> eliability <u>A</u> nalysis) | The importance of human errors in Coast Guard operations and the complexity of some operations/procedures make HRA potentially useful for special situations as a supplement to other techniques (especially WISE analysis) |
| CCFA (<u>C</u> ommon <u>C</u> ause <u>F</u> ailure Analysis) | When a situation is complex enough to require FTA/ETA, the potential for common cause failures cannot be overlooked. CCFA should always be applied (in some level of detail) with FTA/ETA |

Section 7 of Attachment A discusses the detailed risk analysis techniques in more detail. Attachments D and E are examples of a detailed risk analysis performed for the Coast Guard.

4.2 Risk-based Safety Survey Process

Although risk analyses are useful for determining what types and levels of protection should be in place to effectively control the risks of potential losses, the benefits of such analyses can be realized only if proper field implementation of the planned protections is accomplished. Traditional safety surveys are typically audits using a systematic process (e.g., checklist) to assess compliance with requirements. They help to manage risk by ensuring that requirements specifying protections/safeguards are being implemented correctly.

The risk-based safety survey process uses predictive as well as historical risk information to focus survey resources on issues associated with the most significant risks. A risk-based safety

survey helps the organization manage risk by ensuring that both internal/external requirements specifying protections/safeguards and other safeguards identified in the coarse risk analysis are being implemented correctly (See Figure 4.7). The process also includes methods for determining the root cause of deficiencies and focusing corrective action resources on the most significant risk issues.

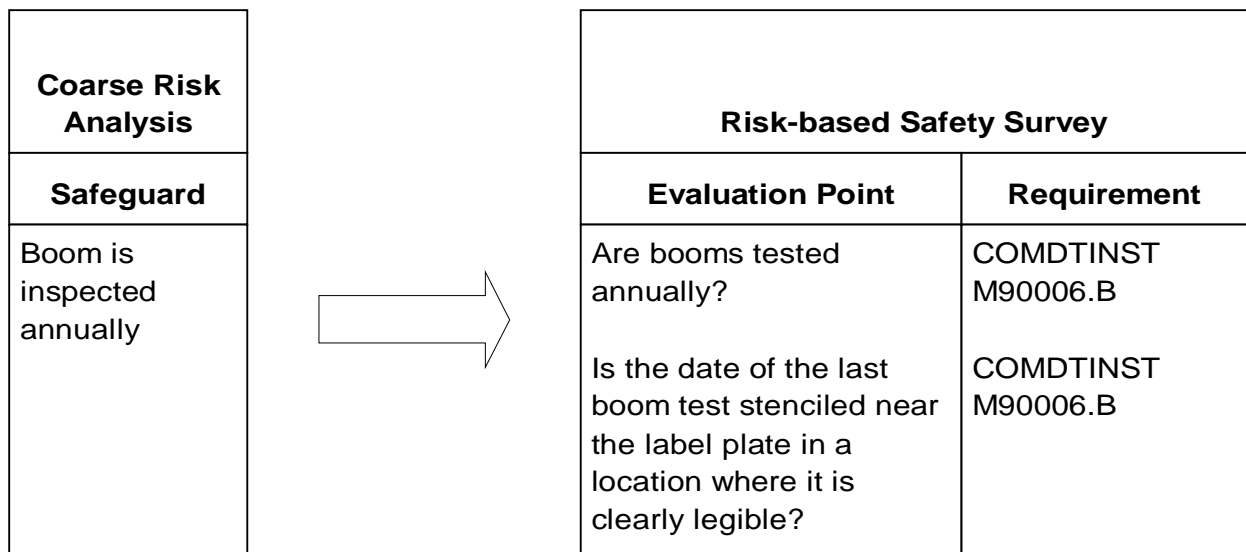


Figure 4.7 Basis for the Risk-based Safety Survey Process

The objectives of the risk-based safety survey process include:

- Focusing survey attention on the most significant risks
- Providing more objective prioritization of findings than traditional surveys
- Allowing more efficient use of survey resources
- Resolving root causes of findings
- Developing safeguard dependability information
- Improving Coast Guard standards and requirements

A risk-based safety survey involves:

- Focusing field observations and reviews on the most risk significant areas
- Identifying nonconformances to requirements as well as nonconformance trends through interviews with personnel, field observations, and documentation reviews
- Determining the underlying root cause(s) of findings

- Prioritizing the findings and resolving higher risk findings first to efficiently and economically use resources
- Tracking the resolution of findings to ensure recommendations for correcting problems are resolved in a timely manner

The risk-based safety survey process places the responsibility and authority for ensuring that planned protections are in place and working effectively on the unit commanding officers and their staffs. The units must understand the required protective measures and make implementation a high priority for effective loss prevention. The risk-based safety survey process assumes that acceptance of this basic obligation exists and that units are conducting their own self-surveys to verify their conformance with established requirements to supplement risk-based safety surveys by third parties (e.g., MLC personnel independent of the unit being evaluated). These third-party surveys complement (not replace) unit self-surveys.

4.2.1 Risk-based Safety Survey Steps

There are five major steps in the risk-based safety survey process:

(1) Plan a safety survey — Planning a survey involves identifying the scope of the survey and preparing for the survey. A key factor in the planning process is the risk prioritization of the evaluation points (checklist items). The risk associated with each evaluation point is determined by combining information from:

- an applicable coarse risk analysis using the link shown in Figure 4.7,
- past mishaps (losses), and
- past safety survey findings.

(2) Assess the requirements/evaluation points and record findings — This task is the actual survey of the unit. Survey team members canvass the unit, reviewing evaluation points. The survey includes equipment inspections, personnel interviews, and documentation reviews. Findings are deficiencies in meeting the intent of an evaluation point.

(3) Identify root causes of findings — Determining the underlying causes of a deficiency and correcting them helps to ensure that the deficiency does not occur again and prevents the underlying causes from contributing to other types of deficiencies and losses.

Root cause analysis should be performed at some level of detail for each finding. For some findings, the simple question “why?” is enough to determine a root cause. Other findings may require more rigor (e.g., 5 Whys technique, Root Cause Map™ technique) to find the root causes. The level of detail and the number of findings investigated with root cause analysis is left to the discretion of the survey team.

- (4) **Determine the risk impact of findings** — This step of the process involves assigning a relative risk weighting to each finding that characterizes the finding's potential impact on unit risk (from the coarse risk analysis). This step uses the relationship shown in Figure 4.7. Risk impact is the foundation for prioritizing the findings for resolution and other tasks in the safety survey process.
- (5) **Document the results and resolve the findings** — The safety survey visit is concluded with an outbrief highlighting the results of the survey. The results are also documented in a safety survey report that is submitted to the unit command, and the findings are documented in a findings database. These steps are discussed in significant detail in Section 8 of Attachment A.

4.2.2 Risk-based Safety Survey Results

The risk-based safety survey process provides feedback about the effectiveness of safeguards designed to control risk of potential losses. This feedback is in the form of findings. Figure 4.8 is an example of determining the risk impact of a finding. All findings from a risk-based safety survey would be analyzed and prioritized so they can be resolved in a cost-effective manner and so that higher risk issues are addressed first. Section 8 of Attachment A provides the details of obtaining this risk-based safety survey result and others. Attachment F provides an example of a risk-based safety survey that was performed on a Coast Guard vessel.

Figure 4.8 shows the determination of the risk impact of a risk-based safety survey finding. The method for this determination involves estimating the change in risk of the coarse risk analysis deviation(s) associated with the evaluation point if the finding (deficiency in a safeguard) is left uncorrected. The revised frequency scores in Figure 4.8 represent the characterization of the coarse risk analysis deviation if the finding is left uncorrected. The change in RIN (with risk expressed within parentheses as increased dollar/year loss) is associated with a risk impact level.

| Finding | Evaluation Point | Affected Deviation (Operation/ Evolution Function Deviation) | Baseline Frequency Scores | | | Revised Frequency Scores | | | Change in RIN† (Risk*) | Risk Impact |
|---|------------------|--|---------------------------------|---|---|--------------------------------|---|---|------------------------------|-------------|
| | | | A/B | C | D | A/B | C | D | | |
| No record of a crane inspection being performed for 2 years | N003 | Working aids to navigation <i>Operating lifting equipment</i> Loss of support | 2 | 3 | 4 | 5 | 6 | 7 | 9.0 (\$90,000) | Medium |

† Risk Index Number

* Estimated economic risk impact based on a change in risk of an associated coarse risk analysis deviation.

Figure 4.8 Risk Impact of a Risk-based Safety Survey Finding

Figure 4.9 is an example of the results of a root cause analysis of a finding. There were two root causes discovered for this finding, and two actions were suggested.

| Finding | Root Cause(s) | Suggested Actions |
|--|--|---|
| Portable winch cable had not been weight tested in 3 years Background Three years ago, the Coast Guard vessel purchased two portable winches for engine room maintenance. The vessel had previously not had this type of equipment in its inventory | No policy or procedure to ensure new acquisitions are added to the vessel test and inspection program No policy or procedure requiring personnel to verify that certifications were up-to-date before using equipment | Develop guidance for adding new acquisitions to appropriate equipment logs such as test and inspection programs Develop guidance verifying certifications of equipment before use, and train personnel on the guidance |

Figure 4.9 Results of a Root Cause Analysis

4.3 Risk Analysis and Risk-based Safety Survey Process Integration

The risk analysis and risk-based safety survey processes are tightly integrated through an exchange of important risk information. Figure 4.10 shows the information exchanges. The integration of the two processes improves the Coast Guard's ability to manage the risks associated with its operations.

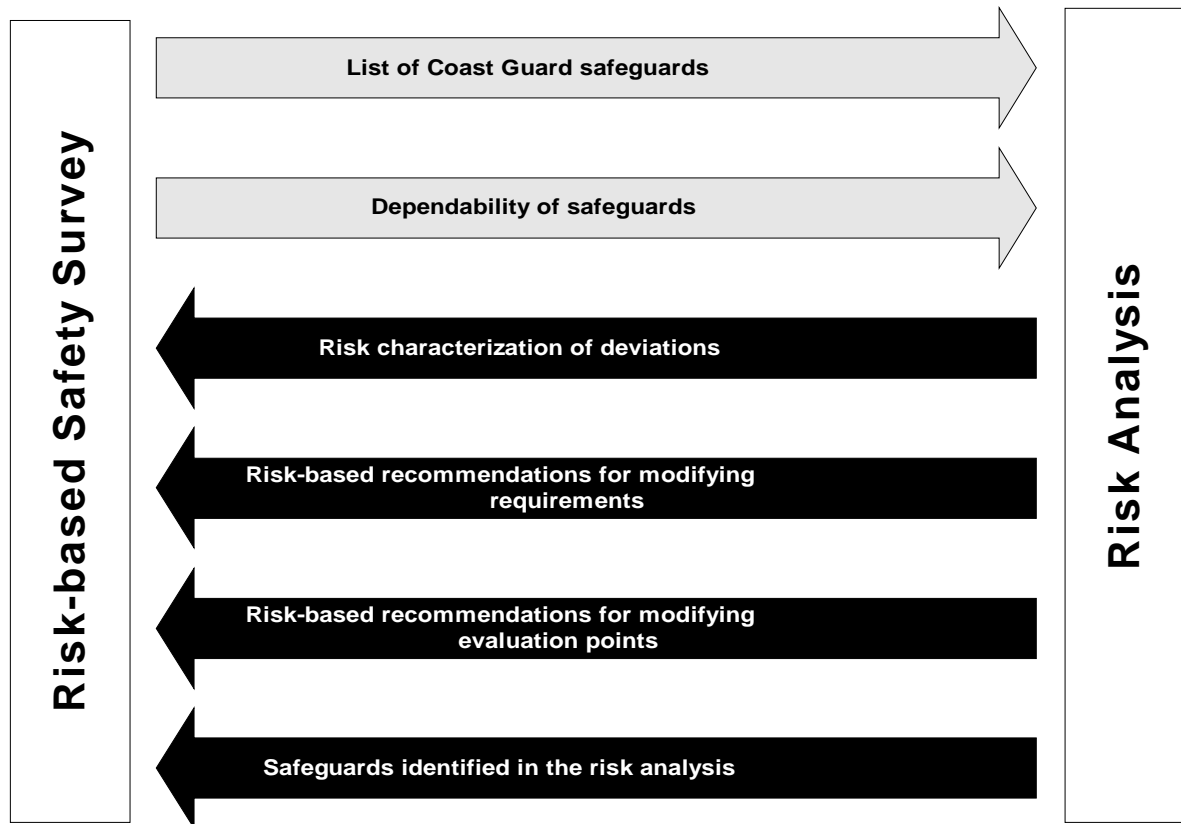


Figure 4.10 IRA Information Exchanges

4.4 Making Decisions Using the IRA Process

The IRA process is a management tool that can be used at each stage of the life cycle of activities to make decisions. The specific part of the IRA process used will depend on the type of risk-based information required for the decision a Coast Guard manager is trying to make. As an example, Table 4.3 provides vessel life cycle activities, how the risk-based information from the IRA process may be used to make decisions, and example outcomes of using the information.

Sections 5 and 8 of Attachment A expand this table to include specific element(s) of the IRA process that help make these decisions.

Table 4.3 Uses of the IRA Process for Vessel Life Cycle Activities

| Use of IRA Process | Example Outcomes |
|--|---|
| Procurement | |
| Identification of major hazards and associated risks (including human factors issues) and required controls while developing bid specifications for major acquisitions (e.g., new vessels or major onboard systems) | Requiring built-in redundancy for specific components of a vessel's automated navigation system |
| Risk-based selection among competing design alternatives for major acquisitions | Determining (and documenting) that Design A provides "best value" to the Coast Guard because it poses significantly less risk of major losses than Design B, which is slightly less expensive |
| Construction, Fabrication, and Commissioning | |
| Identification of design weaknesses, safe operating limits, critical preventive maintenance tasks, human factors issues, etc., for selected systems (i.e., those that could lead to losses of interest) after the final design is complete for major acquisitions | Requiring an audible alarm and semiannual calibration of fathometers for a vessel |
| Evaluation of proposed changes and identified nonconformances from the approved design | Approving a proposed field change (or a recognized nonconformance) in the routing of a high-pressure steam line because the new routing poses no identifiable increase in risks to personnel or equipment |
| Vessel Operations and Maintenance | |
| Identification of precautions to be taken in performing operations outside of prescribed limits (case-by-case basis for decisions made by vessel-board personnel) | Establishing more stringent maneuvering restrictions and additional watch requirements for performing search and rescue (SAR) operations in extreme weather conditions that would normally cause discontinuation of the operation |
| Identification of precautions to be taken in preparation for performing operations when relevant vessel systems will be unavailable (case-by-case basis for operations/efficiencies identified by vessel-board personnel) | Posting additional watches and conducting special operations briefings before conducting an operation |
| Evaluation of proposed changes and identified nonconformances from the standard vessel configuration (case-by-case basis for changes suggested and approved by vessel-board personnel) | Rejecting a request to temporarily store equipment on the deck while a storage locker is being replaced because the movement of the equipment under expected high seas could lead to losses of interest |
| Identification of weaknesses in procedures that could lead to losses of interest (case-by-case basis for procedures developed and approved by vessel-board personnel) | Revising vague steps of a procedure (e.g., "open the valve slightly") because a human error associated with the operation could lead to a loss of interest |
| Area, District, or Group Management of Operations and Maintenance | |
| Identification of design weaknesses, safe operating limits, critical preventive maintenance tasks, human factors issues, etc., for selected systems (i.e., those that could lead to losses of interest) aboard existing ships that did not receive such reviews before being placed in operation | Recommending redesign of a small craft launching system component that could inadvertently trigger a release of a boat |

Table 4.3 Uses of the IRA Process for Vessel Life Cycle Activities (cont'd)

| Use of IRA Process | Example Outcomes |
|--|---|
| Area, District, or Group Management of Operations and Maintenance (cont'd) | |
| Identification of safe operating limits (from an operations/command perspective rather than a hardware system design perspective, which was addressed during design reviews) and preferred precautions to be taken if operating outside of such restrictions | Prohibiting aircraft fueling operations and other flammable material handling activities until disabled onboard firefighting systems are returned to service, but allowing emergency fueling operations if another onboard pump can be rigged to temporarily provide adequate firefighting capability |
| Identification of critical training topics, standard procedures necessary, etc., for preventing losses of interest | Deciding to write a special procedure and conduct special training for the proper way to launch a new type of small craft (because the operation is significantly different from similar operations with older small craft) |
| Identification of weaknesses in procedures and human factors issues that could lead to losses of interest (for standard procedures applicable to a class of vessels or the entire fleet) | Making the units of pressure referenced in a procedure (e.g., SI units) consistent with those commonly used aboard a vessel and on the vessel's gauges (e.g., English units) to help prevent confusion that could lead to an operating error |
| Evaluation of proposed changes for standard vessel configurations (case-by-case basis for changes approved by group/fleet officers) | Deciding (1) against a crew reduction aboard a WMEC-270 cutter because of unacceptable risks associated with degraded watch standards or (2) in favor of a crew reduction, provided that each vessel is equipped with new navigation and vessel detection systems |
| Monitoring profiles of risks for classes of vessels across the Coast Guard to help understand/manage risks at a fleet level | Determining that a specific class of vessel is the next to receive a major overhaul (or replacement) program because of high loss rates |
| Assigning measures of importance to safety inspection items to help prioritize responses to noted deficiencies | Deferring resolution of a few deficiencies noted during a safety inspection until next fiscal year because the deficiencies do not pose any significant risks of losses |
| Risk-based selection (including consideration of other factors, such as cost) among competing alternatives such as vessel deployment, mission assignments, etc. | Deciding to send Vessel A on an extended international tour because the potential for losses associated with (1) its tour and (2) its absence from its normal station are less than those for Vessel B |
| Decommissioning | |
| Risk-based selection (including consideration of other factors, such as cost and political pressure) among competing alternatives for vessel/station decommissioning | Deciding (and gaining support for the decision) to decommission Vessel B instead of Vessel A, even though there is some political support for keeping Vessel B in service |
| Identification of weaknesses in equipment used for decommissioning and associated procedures that could lead to losses of interest | Modifying the equipment and procedures used to de-inventory hazardous materials from a vessel while the vessel is being decommissioned |

5. IRA Process Development

The Coast Guard recognized the potential benefit in using risk-based information to support decisions concerning the management and control of its assets. The RDC committed to developing a risk assessment process for providing this risk-based information. In 1995, the RDC teamed with JBFA to develop and test a Coast Guard risk assessment process, which became the IRA process.

The RDC and JBFA used a three-phased approach to develop the IRA process. Below is a brief description of each phase.

Phase 1 — identification of the Coast Guard’s risk-based information needs, development of the coarse risk analysis technique, identification of relevant detailed risk analysis tools, development of the framework for the risk-based safety survey process, test applications of the coarse and detailed risk analyses, and development and training of Coast Guard safety professionals on the coarse risk analysis technique.

Phase 2 — refinement of the coarse risk analysis process, development of the risk-based safety survey process, integration of the two processes into the IRA process, validation of the IRA process on Coast Guard vessels, revisions to the training course developed in Phase 1, and training of additional Coast Guard personnel.

Phase 3 — modification of the IRA process for use on shore facilities and validation of the IRA process on Coast Guard shore facilities.

The following sections discuss each of the project phases, including the approach, results, and lessons learned (issues) associated with each phase.

Reminder: During the course of this research project, the term “hazard analysis” was changed to “risk analysis” to better describe the process. Therefore, the term “hazard analysis” will be found in many previous letters, reports, and other work products related to this project. These previous references to hazard analysis should now be interpreted as references to risk analysis.

5.1 Phase 1

The RDC and JBFA met with Coast Guard decision makers and safety professionals to gain understanding of the current Coast Guard processes used for assessing risk and the Coast Guard's expectations for a risk assessment methodology. From these discussions, the RDC and JBFA proposed that the risk assessment methodology consist of two elements: (1) a risk analysis process and (2) a risk-based safety survey process. In general, the risk analysis process would identify risks and provide risk reduction measures where appropriate, and the risk-based safety survey process would enhance the current safety survey process with risk-based information to help ensure that the safeguards designed to reduce risk are effectively implemented in the field. The objectives of Phase 1 were to (1) develop and test a risk analysis methodology and (2) develop the framework for a risk-based safety survey process.

5.1.1 Risk Analysis

From discussions with Coast Guard decision makers and safety professionals, the Coast Guard required a risk analysis methodology that would meet its risk-based information needs without overworking or underworking the issues. To accomplish this, the RDC and JBFA considered a methodology that could analyze issues at two levels of detail. The methodology would include (1) a coarse risk analysis (streamlined analysis) for assessing most situations and (2) a set of detailed risk analysis techniques for specific situations requiring better resolution of results and/or higher certainty in risk characterization of scenarios.

5.1.1.1 Coarse Risk Analysis

Approach

Once the Coast Guard's coarse risk analysis needs/expectations were identified, the RDC and JBFA began investigating what hazard evaluation technique (or combination of techniques) would best serve the Coast Guard as the basis for its coarse risk analysis approach. A collection of widely accepted hazard evaluation approaches were considered (e.g., checklist analysis, the traditional safety review, what-if analysis, the traditional process risk analysis, relative ranking tools, FMEA, and HAZOP analysis). Multiple approaches/formats were tested to determine how well they might meet the Coast Guard's needs. Through this refinement process, the RDC and JBFA developed a proposed coarse risk analysis process for the Coast Guard, recognizing that, based on test applications, additional revisions and improvements of the process would likely be

necessary. The proposed process was primarily based on the HAZOP analysis technique used in the petrochemical industry.

HAZOP is an inductive approach that uses a very systematic process for postulating deviations from the design intent for sections of systems and ensuring that appropriate safeguards are in place to help prevent losses. The approach generates qualitative descriptions of potential losses (deviations, causes, mishaps, and safeguards) as well as lists of recommendations for reducing risks. HAZOP was easily adapted to incorporate frequency estimates for potential losses and the operations/evolutions and functions of Coast Guard units.

The RDC and JBFA tested the proposed coarse risk analysis to evaluate the effectiveness and efficiency of the methodology by working with three different teams of Coast Guard personnel. These teams participated in mock risk analysis sessions, testing various parts of the proposed coarse risk analysis process. The lessons learned from the test application were used to modify the proposed process, and the baseline coarse risk analysis process was created.

As a test of the baseline methodology, the RDC and JBFA performed a coarse risk analysis on two vessel platforms, the *USCGC KENNEBEC* (a WLIC-160 vessel) and the *USCGC HARRIET LANE* (a WMEC-270 vessel).

In addition to testing the methodology, the Coast Guard wanted to ensure that Coast Guard safety professionals could be trained to perform the coarse risk analysis process. To accomplish this, the RDC and JBFA developed a week-long training course that included discussions on risk and general risk analysis as well as training on performing the coarse risk analysis process. This training course was conducted for both MLC-Pacific (MLC-PAC) and MLC-Atlantic (MLC-LANT) safety professionals and included simulated analyses aboard actual Coast Guard vessels.

Results

In general, the test applications of the methodology on *USCGCs KENNEBEC* and *HARRIET LANE* proceeded very well. For a high-level analysis, the coarse risk analysis methodology effectively highlighted the most significant risk contributors and provided enough detail to develop meaningful recommendations for reducing risk. The results of the analyses provided the Coast Guard with the appropriate level of detail for making risk-based decisions.

The training session was successful in teaching Coast Guard safety professionals to perform the coarse risk analysis process. During the session, the safety professionals provided valuable feedback concerning the methodology that the RDC and JBFA could use to improve the effectiveness and efficiency of the process. A workshop was conducted at the end of the week, providing the safety professionals with the opportunity to use the analysis technique on several vessel activities. The workshop successfully demonstrated that the coarse risk analysis process was sufficiently structured to be used by Coast Guard personnel who have modest risk analysis experience.

The RDC and JBFA planned to refine the coarse risk analysis process in Phase 2 and modify the process where appropriate for integration with the proposed risk-based safety survey process.

Lessons Learned

Two significant issues arose during Phase 1:

- (1) While testing the baseline coarse risk analysis (and also during the training session), the RDC and JBFA found that it worked best to focus the analysis on one operation/evolution at a time. The baseline methodology was restructured to provide this focus. This is in contrast to evaluating abnormal conditions (deviations) across all operations/evolutions simultaneously. The modification improved the subject matter experts' understanding and participation in the analysis.
- (2) As the baseline coarse risk analysis was tested, it was apparent that a software tool was needed to help perform the analysis, maintain the analysis data, and manipulate the analysis data into various results.

5.1.1.2 Detailed Risk Analysis

Approach

Many types of detailed risk analysis techniques (both qualitative and quantitative in nature) have been developed over the past 30 to 40 years to help analysts in a variety of industries systematically assess the hazards in their activities and the levels of risk associated with those hazards. The RDC and JBFA investigated what hazard evaluation techniques would best serve the Coast Guard as detailed risk analysis tools in specific situations. Rather than spending

resources trying to create new techniques (or significantly customizing existing techniques) for the Coast Guard, the RDC and JBFA approached this phase of the risk analysis project by recommending that the Coast Guard adopt a small set of the widely recognized, standard hazard evaluation techniques that provide a broad range of analysis capabilities as part of the Coast Guard's overall risk analysis system. The rationale for using "off-the-shelf" techniques included the following points:

- Existing detailed risk analysis techniques have been repeatedly used in a variety of applications with strong histories of success when techniques are prudently selected for analysis applications
- The coarse risk analysis methodology will satisfy most of the Coast Guard's hazard evaluation needs; therefore, detailed risk analysis methodologies are somewhat less important and do not warrant the resources required to create specialized tools
- The expected use of outside contractors (in larger analyses) to support Coast Guard hazard evaluation needs is simplified when standard analysis approaches are specified
- Users/reviewers of risk analysis results have greater confidence in the quality of results when widely recognized methodologies are followed

To demonstrate the effectiveness of a detailed risk analysis technique, the RDC and JBFA reviewed WMEC-270 small boat operations and WLIC-160 aids to navigation (ATON) deck operations using several techniques. Because these activities were included in the testing of the baseline coarse risk analysis, choosing them provides an opportunity to compare detailed risk analysis results and coarse risk analysis results.

Results

The standard list of detailed risk analysis techniques was identified. This list is documented in Section 4.1.2 of this report, Table 4.2. Section 7 of Attachment A contains a detailed discussion of these techniques.

The assessment of WMEC-270 small boat operations was performed using the WISE analysis technique coupled with a human error (error-likely situation) review and a procedural review. The analysis confirmed the risk assessment performed by the coarse risk analysis. However, the detailed study provided a more focused review of small boat operations and thus developed recommendations that the coarse risk analysis would not have produced (nor should have produced due to the level of resolution needed from the coarse risk analysis). The analysis

was very successful in demonstrating the benefits of detailed risk analysis. Attachment D contains the results of this detailed risk analysis.

The detailed analysis of WLIC-160 ATON deck operations was performed using the what-if analysis technique. This technique was considered most appropriate to ATON operations because (1) personnel experienced in ATON operations were available for valuable brainstorming discussions and (2) more structured analysis techniques (such as HAZOP or FMEA) were not needed to assess the risks associated with the complexity of this operation. As expected, the what-if analysis refined the coarse risk analysis results with more detailed descriptions of specific causes of certain mishaps and additional recommendations for risk reduction. This analysis was also a successful demonstration of a detailed analysis technique. Attachment E contains the results of this detailed risk analysis.

Lessons Learned

The detailed risk analysis process worked well, and no significant issues arose as a result of Phase 1.

5.1.2 Risk-based Safety Survey

Approach

The Coast Guard relies heavily on conformance to safety standards to ensure the safety of its personnel and assets. Safety professionals within the Coast Guard are very familiar with the safety standards and their application. The Coast Guard wishes to capitalize on this corporate knowledge to improve safety standards and unit risk assessments.

The RDC and JBFA met with Coast Guard safety professionals to determine the current state of assessing and implementing safety standards. The RDC and JBFA sought to understand how the safety standards could be organized and prioritized from a risk impact perspective to improve the Coast Guard safety survey process. The Coast Guard desired to maximize the benefit of safety surveys while reducing the amount of time required by the Coast Guard safety professionals to perform safety surveys.

The RDC and JBFA polled private industry and the Navy to understand their approach to performing safety surveys and using safety survey information. As a result of this investigation,

the RDC and JBFA identified two significant ways to meet the Coast Guard's desires: (1) focus safety surveys on higher risk issues and (2) prioritize safety survey findings for efficient resolution.

The RDC and JBFA investigated ways to focus safety surveys on the higher risk issues by prioritizing the survey evaluation points according to the risk. The most logical method for this prioritization appeared to be by using risk-based information from the risk analysis process. Focusing on the higher risk issues ensures an effective survey of the dominant risk contributors while potentially reducing the work load of the safety professionals. Also, reviewing the risk associated with evaluation points can eliminate requirements that add little value to the safety survey process.

The RDC and JBFA also investigated methods to effectively and efficiently focus Coast Guard resources on resolving findings (or deficiencies) identified as a result of the safety survey. A method is needed for prioritizing findings so that resources can be focused on high risk issues. To prioritize findings, the risk-based information from the risk analysis process can be used for determining the impact a finding has on the risk of a Coast Guard unit. Once the risk impact of a finding is determined, the Coast Guard can identify a resolution order.

Results

The RDC and JBFA proposed a framework for a risk-based safety survey process. The process developed from this framework would meet the Coast Guard's risk-based information needs and desires for an efficient and effective safety survey process. The risk-based safety survey process would be developed and validated in Phase 2. Where appropriate, the development would focus on integration with the risk analysis process.

Lessons Learned

The risk-based safety survey framework was developed, and no significant issues arose as a result of Phase 1.

5.2 Phase 2

The objectives of Phase 2 were to refine the risk analysis process, formalize the risk-based safety survey process, integrate the processes into the IRA process, train Coast Guard personnel

to conduct a risk analysis and a risk-based safety survey, and validate the IRA process on vessel applications. The work on the risk analysis process consisted of refinement of the coarse risk analysis process and validation of the coarse and detailed risk analysis processes on vessel applications. The proposed risk-based safety survey process from Phase 1 was formalized and validated on a vessel application. Integration of the two processes was tested during validation of the risk-based safety survey process. The training course developed in Phase 1 was updated to reflect modifications to the processes, and additional Coast Guard personnel were trained.

5.2.1 Coarse Risk Analysis

Approach

The coarse risk analysis process was refined to address the issues identified in Phase 1. The major change in the process was to restructure the analysis around operations/evolutions and focus on one operation/evolution at a time during the analysis. The RDC and JBFA validated the refined coarse risk analysis by performing an analysis of the operations/evolutions of the *USCGC MELLON* (a WHEC-378 vessel) during a 1-week analysis session. Coast Guard safety professionals led the validation exercise with the assistance of the RDC and JBFA. This test application also validated the success of the training course (described in Phase 1) in equipping Coast Guard safety professionals to lead these analyses.

In support of the test analysis, an off-the-shelf software tool was adapted for documenting the raw data from the analysis.

Results

The coarse risk analysis validation on the *USCGC MELLON* proved to be successful and very beneficial in revealing potential areas for improvement in the coarse risk analysis process. The analysis team successfully analyzed the majority of the operations/evolutions of the *USCGC MELLON*, developed a risk profile for the vessel, and generated numerous risk reduction recommendations.

Lessons learned from using the software tool to document the analysis were incorporated into the development of a software tool to support the IRA process.

The Coast Guard safety professionals successfully led the test application. The training they received during the week-long training course (described in Phase 1) proved to be successful in preparing them for leading a coarse risk analysis.

Lessons Learned

Two significant issues arose during the validation of the coarse risk analysis:

- (1) The RDC and JBFA wrestled with the most appropriate and effective method to represent the RIN, which is a representation of risk associated with Coast Guard activities. The baseline coarse risk analysis method for calculating the RIN used a simple method that included risk scores for Class A/B and Class C/D mishap categories. Testing the methodology revealed that this method inflated the risk contribution of high consequence losses (Class A and Class B mishaps) in the RIN. To correct this, the method for calculating the RIN was modified. The new method was tested and corrected the initial problem, but introduced another. Using the new method for calculating the RIN, the lowest consequence losses (Class D mishaps) became the dominant factor in the Class C/D mishap category score. The new method resulted in Class D mishaps inflating the risk contribution of the Class C/D mishap category in the RIN.
The final resolution was to divide the Class C/D mishap category into a Class C mishap category and a Class D mishap category. The revised methodology assigns risk scores to Class A/B, Class C, and Class D mishaps. This change was incorporated into the methodology and tested in Phase 3.
- (2) Functions as defined in the baseline coarse risk analysis process describe (1) key activities for accomplishing operations/evolutions (e.g., *maneuvering the vessel*) or (2) key activities for controlling different types of hazards (e.g., *controlling physical hazards*). This approach provided sufficient analysis structure to identify important problem areas, but did have some weaknesses. The approach segregated safety-related issues from operational issues, overlooked the interrelationship of several functions, and overlooked potential problems associated with loss of capability to perform key activities as well as poor quality in performing those activities.

These weaknesses caused some confusion for analysis team leaders and team members. In addition, some Coast Guard safety professionals expressed concern about the message that

separating “safety” and “operational” issues sends to Coast Guard managers (i.e., Would it lessen the impact of safety concerns?).

The resolution for this issue involved revising function definitions (and associated deviations) to focus on fundamental activities that occur for a unit (e.g., *operating vessels, vehicles, aircraft, or equipment; operating/maintaining structures; and providing services/utilities*). A diverse set of deviations is included for each function. These deviations cover (1) loss of the function, (2) incorrect execution of the function, and (3) a variety of hazardous exposures that could occur while performing the function (including associated maintenance activities). The new functions were tested in Phase 3.

5.2.2 Detailed Risk Analysis

Approach

In Phase 2, the Coast Guard desired to perform an additional test of a detailed risk analysis technique. The detailed risk analysis approach meets the Coast Guard’s detailed analysis objectives and was not modified from Phase 1.

The Coast Guard chose to perform an analysis of incinerator installations on board WHEC-378 vessels. The incinerator installation on board the *USCGC MUNRO* was selected by the Coast Guard as the subject of the detailed risk analysis, with the intent of applying any lessons learned from the analysis to that installation (as appropriate) and to subsequent installations on other cutters (especially other cutters in the same class).

Results

The RDC and JBFA successfully performed a what-if/checklist analysis on the incinerator installation. Coast Guard vessel and shore-based personnel participated in the analysis. Several recommendations for improving the incinerator installation were generated from the detailed risk analysis.

Lessons Learned

The detailed risk analysis process worked well, and no significant issues arose as a result of Phase 2.

5.2.3 Risk-based Safety Survey (Phase 2)

Approach

The risk-based safety survey process proposed in Phase 1 was formalized and integrated with the coarse risk analysis process. The RDC and JBFA determined the information required from the coarse risk analysis process and developed detailed steps for prioritizing evaluation points and risk ranking survey findings for resolution. Root cause analysis techniques were investigated for appropriately resolving findings. The RDC, JBFA, and MLC-PAC (kse) validated the risk-based safety survey process on the *USCGC SHERMAN* (a WHEC-378 vessel). By performing the process on a WHEC-378, integration of the coarse risk analysis and risk-based safety survey could also be tested.

Results

The RDC and JBFA used the results of the WHEC-378 coarse risk analysis and past safety survey findings information (from MLC safety professionals) to prioritize the safety survey evaluation points. The safety survey tested on the host vessel (*USCGC SHERMAN*) focused on the higher risk evaluation points. The survey produced several meaningful findings. The RDC, JBFA, and MLC safety professionals used the IRA process to rank the findings according to their impact on overall vessel risk. The risk-ranked findings were prioritized for resolution and presented to the vessel command. The IRA process identified that some findings did not require immediate resolution due to their very low risk impact to the vessel.

The validation was successful in testing the risk-based safety survey process and the methodology for integrating the coarse risk analysis and risk-based safety survey processes. Attachment F documents the results of this risk-based safety survey and is included as an example of a risk-based safety survey. (The ultimate formats of reports for the Coast Guard are left to the individual commands.)

Lessons Learned

The risk-based safety survey process worked well, and no significant issues arose as a result of Phase 2.

5.3 Phase 3

The objective of Phase 3 was to refine the IRA process for shore facility applications and to validate the process. The RDC and JBFA reviewed the coarse risk analysis and risk-based safety survey processes to determine differences in applying these processes to shore facilities. Upon review, the risk-based safety survey process appeared to be the same when applied to either type of Coast Guard unit and would not need modifications. However, the coarse risk analysis would need modifications and would also need to be tested on shore facilities. The main objective of Phase 3 was to make necessary adjustments to the coarse risk analysis process and test it on shore facilities. A secondary objective was to test the risk-based safety survey process with unit safety supervisors to reduce the monitoring burden from the MLC staffs. In addition, the RDC and JBFA needed to ensure that these adjustments maintain the effectiveness of the process when it is reapplied to vessels.

5.3.1 Coarse Risk Analysis

Approach

When applying the coarse risk analysis process to shore facilities, the RDC and JBFA sought to maintain consistency (to the maximum extent possible) with the coarse risk analysis process as it is applied to vessels. The RDC and JBFA tested portions of the process on hypothetical shore facility situations and found that the core structure of the analysis technique also worked well for shore facilities. However, three major issues were discovered: (1) the operations/evolutions are different for shore facilities, (2) some functions are not applicable to shore facilities and others are required, and (3) the coarse risk analysis process needs to be able to assign risk to a specific location for shore facilities (when needed).

Shore facilities have a different mission from vessels and, therefore, their operations/evolutions are different. In fact, different types of shore facilities (e.g., Integrated Support Commands [ISCs], Marine Safety Offices [MSOs]) have a different set of operations/evolutions due to their different missions. A new set of operations/evolutions was developed for each type of shore facility.

Several vessel functions (e.g., *providing ballasting services*) are not applicable to shore facilities, and several shore facility functions (e.g., *operating powered vehicles*) are not included in the vessel function list. Upon further research, the RDC and JBFA also found that different

types of shore facilities have a slightly different set of functions (the MSO function list contains a number of inspection functions). The RDC and JBFA developed the shore facility function lists (ISC and MSO) from the vessel function list by making the necessary modifications to the vessel list.

Because shore facilities involve numerous types of buildings and structures (e.g., piers, parking lots, roads), it was obvious that a method for assigning risk to individual locations would improve the effectiveness of the coarse risk analysis for shore facilities. The RDC and JBFA modified the methodology in such a way that the resulting modified coarse risk analysis process could be used for shore and vessel applications.

The modified approach evaluates deviations in the same manner as before, except the analysis team will assess how the deviation risk is distributed across the different locations within the facility (if more than one location is an issue). The new methodology is flexible enough to allow the analysis to proceed without assessing location risk. This gives the Coast Guard analyst the option to perform the analysis as before (without assigning risk to locations) if that information is needed.

The RDC and JBFA tested the resulting coarse risk analysis process on an ISC and an MSO shore facility. The RDC and JBFA, with the support of MLC-LANT (kse), also tested the modified process on a WMEC-210 in support of the Paragon project.

Results

The RDC and JBFA validated the new coarse risk analysis process on the ISC in Seattle, Washington, the MSO in New Orleans, Louisiana, and the *USCGC VENTUROUS* (a WMEC-210 vessel). The ISC analysis included assessing the risk associated with locations. The MSO and WMEC-210 analyses did not assess location risk. All three validations produced risk profiles of the facilities and vessel, and meaningful recommendations for reducing risk. The minor modifications to the coarse risk analysis process were successful. They made the overall IRA process a better risk assessment tool and maintained the ability to assess vessel applications. Attachment B contains the results of the WMEC-210 coarse risk analysis, and Attachment C contains the results of the ISC coarse risk analysis.

Lessons Learned

The coarse risk analysis process worked well, and no significant issues arose as a result of Phase 3.

6. Future Development

The next step for the IRA process is to develop a management system that will manage the IRA process, generate the required IRA process data, and ensure the data are accessible to Coast Guard managers for decision making. Work will focus on the areas described below.

Developing an IRA Process Software Tool

Because of the complexity involved with managing and manipulating the data produced by the IRA process, the Coast Guard identified the need for a software tool to assist in the implementation of the process. Development of the IRA process software tool began during Phase 3. The RDC and JBFA used the experiences gained from applying the IRA process on shore and vessel applications to develop a conceptual design of the software tool. The conceptual design was accepted and work began on various software modules. The next step is to test a beta version of the software. The IRA process beta version of the software was delivered in the Fall of 1998 and will be released by the R&D Center early in 1999.

Developing a Management System for the IRA Process

JBFA will work with the Coast Guard to develop a management system for the IRA process. This system will define the roles and responsibilities involved in implementing the IRA process, define the management of the IRA information, and define the interaction of the IRA process with other Coast Guard management systems.

Improving Related Coast Guard Management Systems

JBFA will work with the Coast Guard to identify improvements to Coast Guard management systems that the Coast Guard could make to reduce loss exposure. This will include:

- Identifying deficiencies in current practices where new management systems might be needed to address all aspects of loss prevention
- Improving existing management systems to enhance their effectiveness and/or efficiency in loss prevention
- Prototyping new management systems
- Exploring how the Coast Guard can measure and track the performance of management systems and their effects on loss prevention

7. Concluding Remarks

By understanding the needs of the Coast Guard and following the guiding principles, the RDC and JBFA developed useful techniques and tools that should be both efficient and effective in helping the Coast Guard control its losses and reduce its loss exposure over time. Validation proved the IRA process to be feasible and useful in assessing a wide variety of Coast Guard operations and facilities at various levels of detail. Coast Guard personnel are successfully using the IRA process to understand the change in risk when making changes in vessel staffing and operating procedures. Continued implementation of the process will provide Coast Guard management with information for risk-based decision making, as well as direction for the efficient and effective use of limited Coast Guard resources.

[Attachments A-F are available through the USCG Research and Development. Contact Bert Macesker, 860-441-2726 or bmacesker@rdc.uscg.mil.]

Attachment A

Integrated Risk Assessment (IRA) Manual

The *IRA Manual* is a detailed description of the IRA process. The manual includes an overview of how losses occur, a discussion of risk and common risk analysis methodologies, an overview of the IRA process, and step-by-step instructions for performing and managing the IRA process. This manual is part of the course for training Coast Guard personnel to perform the activities in the IRA process. The analysis of a WHEC-378, with Coast Guard personnel leading the analysis, demonstrated that the course is sufficient to train Coast Guard personnel to conduct assessments.

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Attachment B

Coarse Hazard Analysis of a WMEC-210 Vessel in Support of the Paragon Project

This attachment contains the results of the most recent coarse risk analysis (formerly called coarse hazard analysis) performed on a Coast Guard vessel (WMEC-210). Included are typical results produced by the analysis and the raw data collected during the analysis sessions with the subject matter experts. The analysis supported an actual operational requirement and was lead by personnel from MLC-LANT.

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Attachment C

Coarse Hazard Analysis of the Integrated Support Command (ISC) at Seattle, Washington

This attachment contains the results of a coarse risk analysis (formerly called coarse hazard analysis) performed on a Coast Guard shore facility. Included are typical results produced by the analysis and the raw data collected during the analysis sessions with the subject matter experts.

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Attachment D

Detailed Hazard Analysis of WMEC-270 Small Boat Operations

This attachment contains the results of a detailed risk analysis (formerly called detailed hazard analysis) of WMEC-270 small boat operations. The WISE analysis technique was used in this study, coupled with a human error (error-likely situation) review and a procedural review. Included are typical results produced by the analysis and the raw data collected during the analysis sessions. Because of the specific expertise required, most detailed analyses like this will be performed by outside experts in the techniques, rather than by Coast Guard personnel.

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Attachment E

Detailed Hazard Analysis of WLIC-160 Deck Operations

This attachment contains the results of a detailed risk analysis (formerly called detailed hazard analysis) of WLIC-160 deck operations. The what-if analysis technique was used for this study. Included are typical results produced by the analysis and the raw data collected during the analysis sessions. Because of the specific expertise required, most detailed analyses like this will be performed by outside experts in the techniques, rather than by Coast Guard personnel.

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Attachment F

Risk-based Safety Survey of a WHEC-378 Vessel

This attachment contains the results of a risk-based safety survey performed on a Coast Guard vessel (WMEC-378). The results include findings from the survey, risk impact of the findings, and root cause analysis results of certain findings. This risk-based safety survey report format was generated to illustrate how results could be presented and is not meant to represent a Coast Guard standard. In implementing the IRA process, the Coast Guard will define standard reporting formats.

